Mapping of Potential Intrusion at Coastal Zone in Small Island Using GIS
(Study case: North Sangadji Village)

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Abstract- *A systematic study has been carried out to explore the physicochemical characteristics and Water Quality of groundwater in thirteen chosen sampling stations at Sangadji village North Ternate District in Ternate Island. Water sample from wells in various sites were collected during March to August 2015 and analyzed physicochemical characteristics like EC, Salinity, pH and TDS. The remaining sampling sites show that the several wells in the study area had been an intrusion by saltwater and are not fit for drinking purpose. Furthermore, our integrated study represents a contribution to the future programs for the protection, planning, and management of the terrestrial and marine resources in this coastal area.*

Keywords: *Groundwater, Seawater Intrusion, Coastal Area*

I. INTRODUCTION

The coastal zones are subject to rapid development with growing and conflicting demands on the natural resources, and often they are subject to irreversible degradation. The critical phenomena which mainly affect these areas are coastal erosion, flooding due to river floods or tidal waves or rising sea level, contamination of the aquifers (e.g. salt-wedge intrusion of seawater). Along the coast there are many sites of community interest subjected to a strong in cadence of human activities mainly linked to agriculture and tourism.

According to the Recommendation on Integrated Coastal Zone Management (ICZM) of the European Commission, coastal areas are of great environmental, economic, social and cultural relevance. Therefore, the implementation of suitable monitoring and protection actions is fundamental for their preservation and for assuring the future use of this resource. Such actions have to be based on an ecosystem perspective for preserving coastal environment integrity and functioning and for planning sustainable resource management of both the marine and terrestrial components. Planning and management of natural resources through a dynamic process has to set as its objective the promotion of economic and social welfare of coastal zones.

Unfortunately, coastal plains are often contaminated by sea water intrusion, and the vulnerability to salinization is probably the most common and diffused problem in an aquifer. The extent of saline water intrusion in the coastal area is influenced by the nature of geological formations present, hydraulic gradient, rate of withdrawal of groundwater and its recharge[1].

As vital resource for all people, ground water resources should be protected in order to remain it available use by humans and other living things. Use of water for various purposes should be done wisely by paying attention to the interests of the present and next generation. Aspects of conservation and preservation of water resources should be done by people.

Population in Ternate city expanded rapidly in last few years. It is encourages the increased need of clean water. Population based on data from Statistical Beareu of Ternate City on 2014 shows that number of population was 202.728 and the level of water consumption by an average of 150 L/person/day. Thus, the total water consumption reached 536.295 m3/year. Unfortunately, the local water company (PDAM) cannot provide water for all and service levels reaching only 70.85%.

The difficulty to obtain drinking water sources was the main constraint to the shortage of water especially in the North Ternate District including North Sangadji village. The implication of this condition for Akagaale, as a source of raw water of local water company and located in sangadji village, was decreased significantly not only in capacity but also in quality. Thus give impact to all wells surrounding akegaale.

Geographic information system (GIS) is an efficient and effective tool in solving problems where spatial data are important. Therefore, it is widely used for assessment of water quality and developing solutions for water resources related problems[2]. GIS based spatial distribution mapping and suitability of groundwater quality evaluation for domestic and agricultural purpose[3]. Anbazhagan and Nair (2004) used GIS to represent and understand the spatial variation of various geochemical elements in Panvel Basin, Maharashtra, India[4]. The objectives of this study are determine the saltwater intrusion and measuring of water quality from several shallow wells around akegaale.

II. MATERIALS AND METHODS

2.1. Study Site

Study was conducted in North Sangadji Village, North Ternate District (fig.1).Geographically, this village is bounded on the North by Dufa-Dufa Village, on the South by Sangadji village, on the West by Ternate island district, and on the East by Halmahera strait. It is a coastal village with population numbered 4369 and 1015 households.This village located at coastal vilage with flat topography.

2.2. Sampling and Preservation

As geochemical data, Water samples from thirteen shallow wells were collected at various locations within the study area from March to August 2015 (Table 1). Water sampling was taken at high tide and low tide situation. Several sensitive parameters of water, such as total dissolved solids (TDS), electrical conductivity (EC), salinity and pH were determined using digital *Horiba water quality checker*. Data will show in the table and mapping of saltwater intrusion potential using interpolation with IDW method from software ArcGIS 10.2.

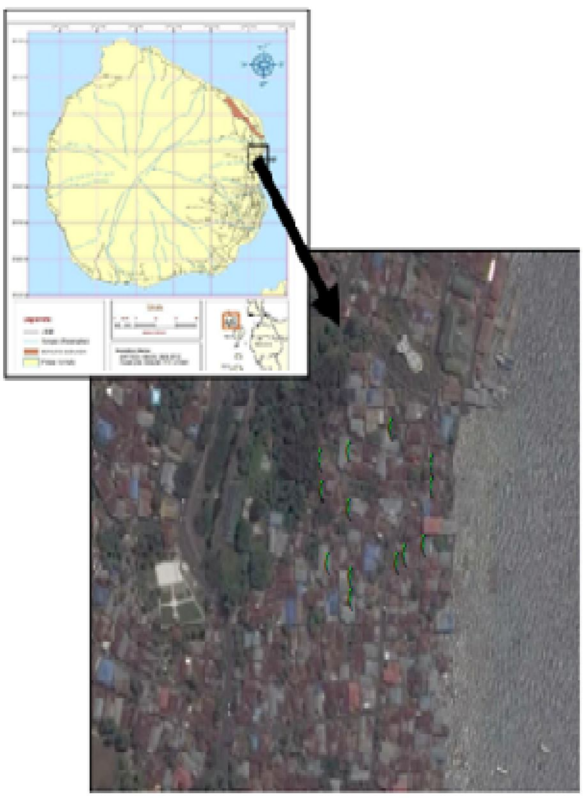


Fig 1. Sampling Site.

Table 1. Sampling Points

ST	Lon	Lat
1	0.81342	127.388
2	0.81319	127.388
3	0.81328	127.388
4	0.81303	127.387
5	0.81322	127.387
6	0.81292	127.388
7	0.81258	127.387
8	0.81236	127.388
9	0.81250	127.388
10	0.81258	127.388
11	0.81264	127.388
12	0.81269	127.388
13	0.81306	127.388

III. RESULT AND DISSCUSSION

3.1. Physicochemical Parameters

Electrical Conductivity

Electrical conductivity (EC) is water's ability to deliver electrical current. In the pure state, water is a poor conductor or an insulator. But, the availability of dissolved ionic substances in water make it’s a conductor. Electrical conductivity is a decisive parameter in determining suitability of water for particular purpose and classified according to electrical conductivity as follows[5]:

EC in µS/cm at 25°C	Classification
< 250	Excellent
250 – 750	Good
750 – 2000	Permissible
2000 – 3000	Doubtful
> 3000	Unsuitable

EC measurement results in all sampling sites showed that the values range were from 1.230 µS/cm – 29.200 µS/cm. However, based on the results observed that EC high value generally can be at the time of measurement with the tide conditions compared with the low tide conditions (fig 2a and b). These results indicate that in several wells already contains ions, for example at site1; site 3 and site 12. Thus the condition of groundwater at study sites was fresh water to brackish water. Several values of EC indicated the kind of water e.g. rainwater from 5.0 to 30 µS/cm; groundwater 30-2000 µS/cm and seawater 45000-55000 µS/cm.

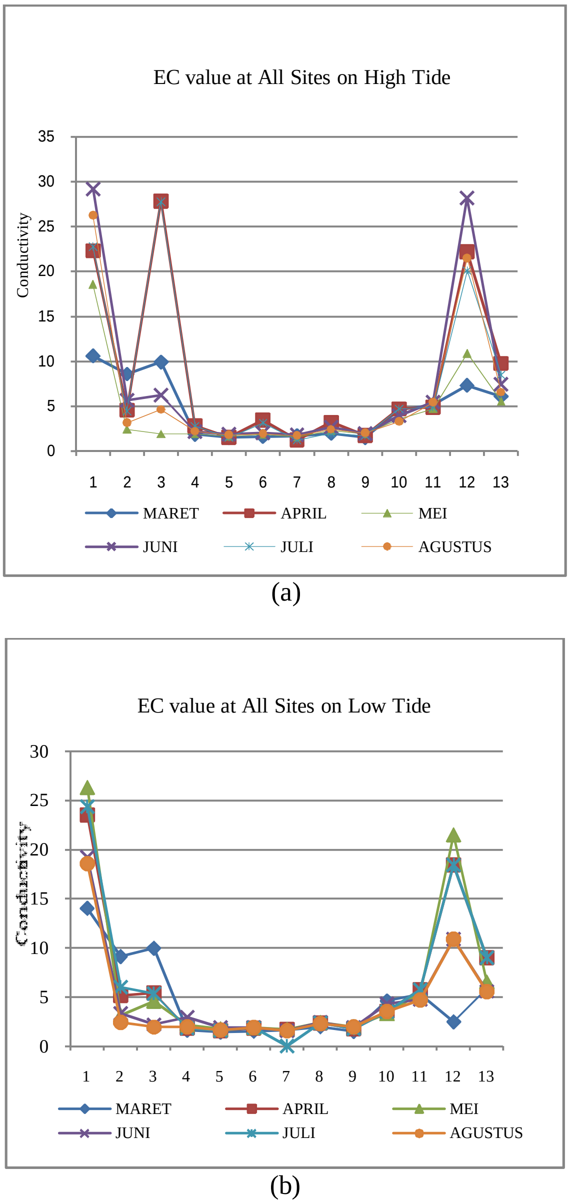


Fig 2. EC Value at Sampling Sites on High (a) and Low Tide (b)

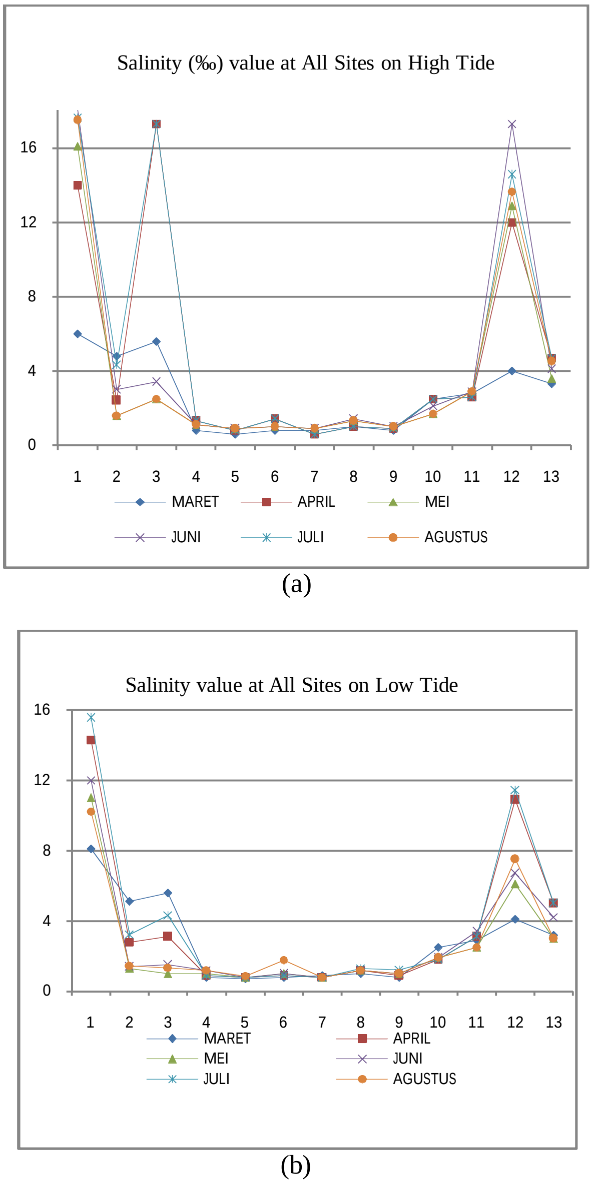


Fig 3. Salinity Value at Sampling Sites on High (a) and Low Tide (b)

Salinity

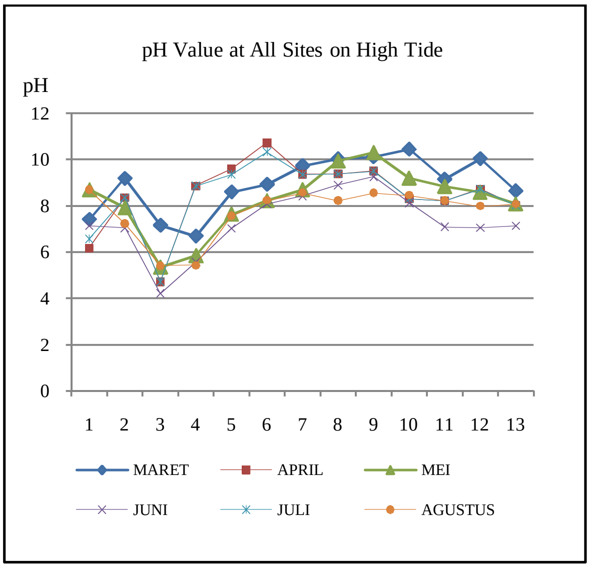
Salinity is a measure of the concentration of total dissolved salts in soil or water, mainly sodium chloride. All natural waters contain soluble salts. The concentration of the salts determines whether the water is of high quality (drinkable or usable for irrigation without need for special precautions) or of low quality (brackish or saline).

The results of the salinity from all sampling locations were variety from 0.6 ‰ - 18.10 ‰. The highest salinity value is generally obtained at site 1, site 3 and site 12. (Fig3 and b). The high salinity indicates the possibility has occurred seawater intrusion in groundwater aquifers in the well. This results show that salinity was difference between low tide and high tide.

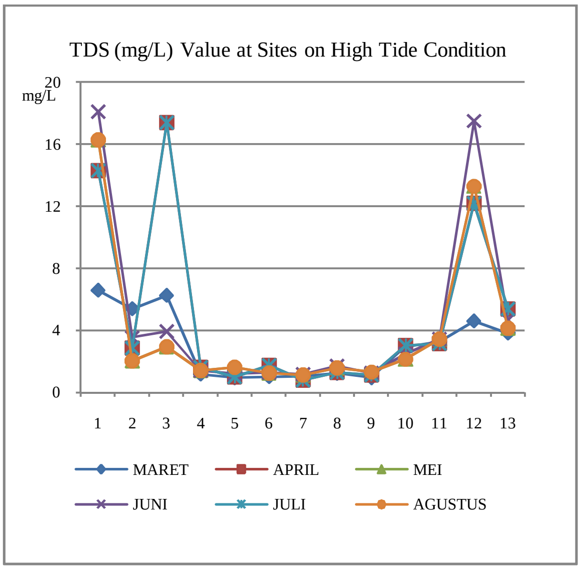
pH

pH value does not have any adverse health effect but it alters taste of water. The higher reduces the germicidal potentiality of chlorine and induces the formation of toxic trihalonethans[6].

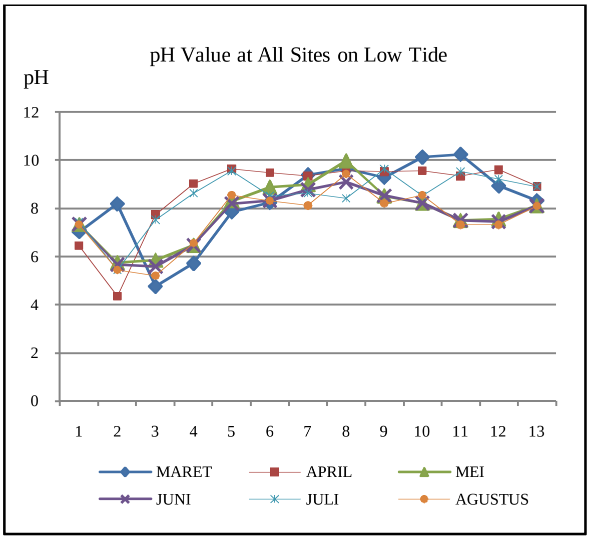
pH values at the sampling site son high tide and low tide found that the pH value ranging between 4:22 - 10.71 (Fig 4 a and b). The wells with a pH value below 7 indicate that the well contains many hydrogen ions; otherwise the wells with pH values above 7 indicate that contains many hydroxyl ions. The higher pH values may be due to a process of chlorination. Most of the natural and ground waters have pH from 4-9 and the majority alkaline due to carbonates and bicarbonates of calcium and magnesium dissolved in water[7].



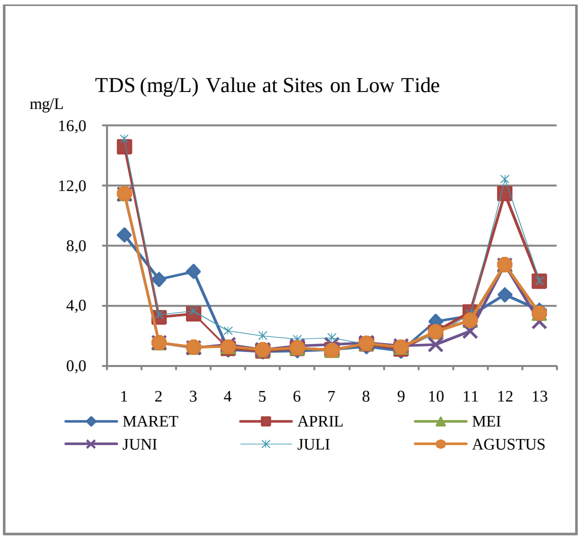
(a)



(a)



(b)



(b)

Fig 4. pH Value at Sampling Sites on High (a) and Low Tide (b)

Fig 5. TDS Value at Sampling Sites on High (a) and Low Tide (b)

Total Dissolved Solid (TDS)

Naturally, ground water contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. The total mass of dissolved constituents is referred to as the *total dissolved solids* (TDS) concentration. In water, all of the dissolved solids are either positively charged ions (cations) or negatively charged ions (anions).

TDS is one of the main quality parameters that dictate suitability of groundwater for any purpose. TDS in this study values from 0.9 – 15.1 mg/L at low tide condition and from 0.79 – 18.1 mg/L at high tide condition (fig 5 a and b).

Electrical measurement is an excellent indicator of TDS which is a measure of salinity that affection the taste of potable water[8]. The variations in Electrical conductivity are based on sedimentary structure and compute of rock. These findings are in conformity with observation[9]. Electric conductivity is a measure of current carrying capacity; it gives a clear idea of soluble salts present in the solids.

In the present studies the electrical conductivity ranged between 1.230-29.200 µS/cm whereas TDS value range from 0.79 – 18.1 mg/l.A higher TDS means that there are more cations and anions in the water. With more ions in the water, the water's electrical conductivity (EC) increases.

By measuring the water's electrical conductivity, we can indirectly determine its TDS concentration. At a high TDS concentration, water becomes saline. Increasing levels of TDS in an aquifer are indicating that the aquifer is contaminated.

Water with a TDS above 500 mg/l is not recommended for use as drinking water (EPA secondary drinking water guidelines). Water with a TDS above 1,500 to 2,600 mg/l (EC greater than 2.25 to 4 mmho/cm) is generally considered problematic for irrigation use on crops with low or medium salt tolerance.

3.2. Mapping of Potential Intrusion

Figure 6 shows a potential intrusion map by saltwater at study area based on integrated four thematic grid data for EC, pH, Salinity and TDS. The spatial integration for groundwater quality mapping was carried out using ArcGIS Spatial Analyst extension. It can be seen in the map that a wells at site 1, site 2 and site 12 had a high potential of intrusion, because those wells are located close with coastal line and drainage, so that, the input of saltwater could recharge groundwater in those wells when it empty.

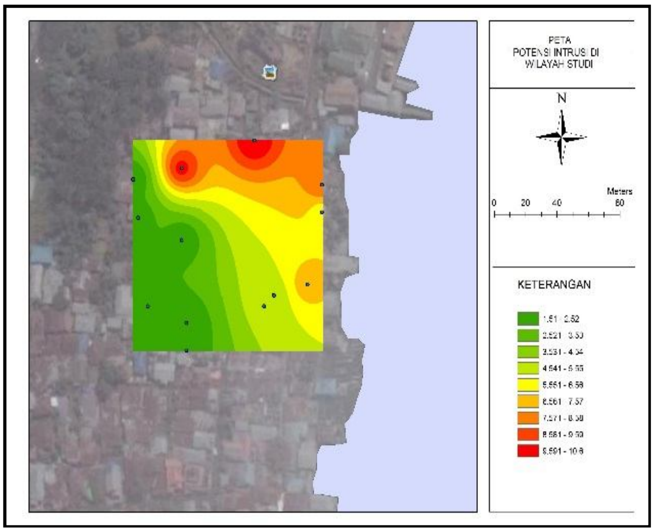


Fig 6**.** Potential Intrusion Map at Study Site.

IV. CONCLUSION

The physic-chemical assessment of groundwater in coastal areas was carried out. The groundwater samples could generally be classified as fresh and moderately hard with salinity values. Majority of the quality parameters investigated were found shows that the groundwater in the study area had been an intrusion by saltwater. There is a need for continuous regulation and quality control monitoring to prevent and control intrusion in order to safeguard human health and to facilitate community attainment of Millennium Development Good(MGD) for water and sanitation.

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